Circular Motion and Gravitation

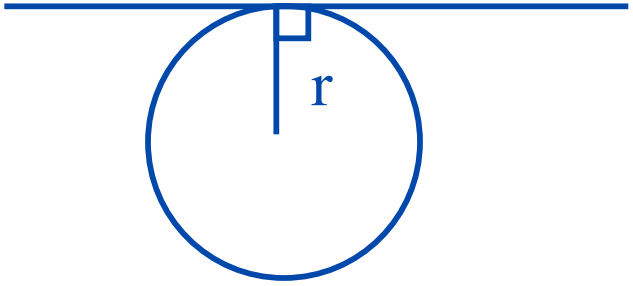
Chapter 7

Terms to be familiar with

- Rotational Motion: Objects that are spinning or rotating about an axis
- Circular Motion: Objects that are traveling in circular paths

More definitions

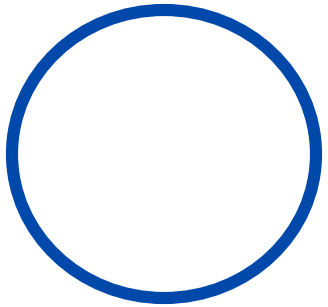
- Uniform Circular Motion (UCM): objects that are traveling in a circular path at a constant radius , at a **constant tangential speed**.
- Tangential speed: $\mathbf{v_T}$-instantaneous velocity vector at any point on the path. This vector is always perpendicular to the radius.



Tangent line is perpendicular to the radius

7.1:Circular Motion

- Speed is distance over time
- S = d/t
- For objects in circular motion, the distance is equal to the circumference of the circle and time is the time period for one complete circle.
- Therefore,
- S = circumference / time period



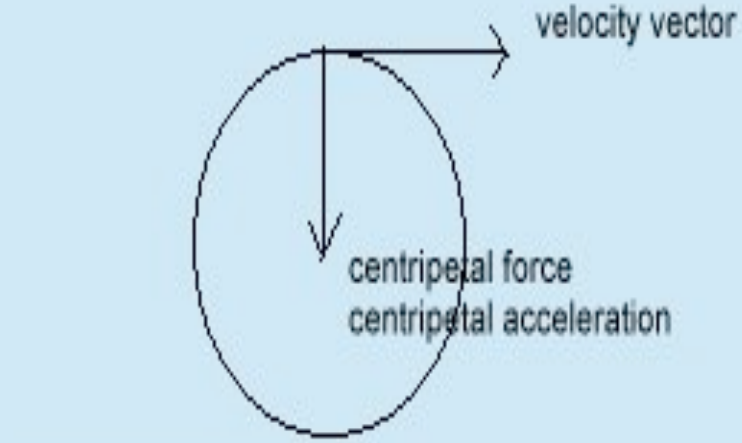
7.1 continued

- $V_t = 2\pi r / T$
  - (T is the time for one revolution or one period)
  - This is essentially distance divided by time because $2\pi r$ is circumference of the path.
  - The velocity vector points tangent to the path of travel

Centripetal Acceleration

- If an object undergoing circular motion it must be changing its direction constantly.
- If an object is changing its direction, it must be changing its velocity
- If an object is changing its velocity, it must be accelerating
- We call this type **centripetal acceleration**

Centripetal Acceleration

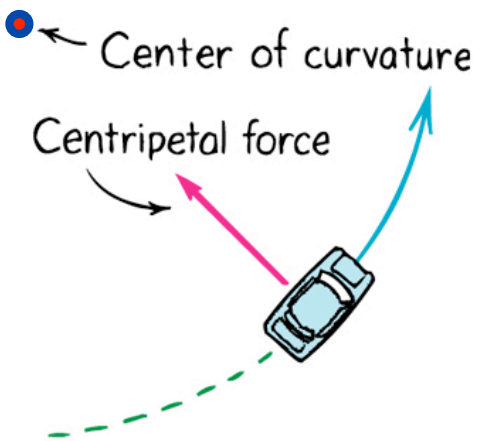


-speed of object is constant
-velocity of object is not constant
-velocity is tangent to the circle at that point
-direction of object is changing
-force and acceleration are directed to the center

- $a_c = v_t^2 / r$
- Centripetal acceleration is the acceleration that exists for objects traveling in a circular path
- Centripetal acceleration (as its name suggests) always points towards the center of the circular path.

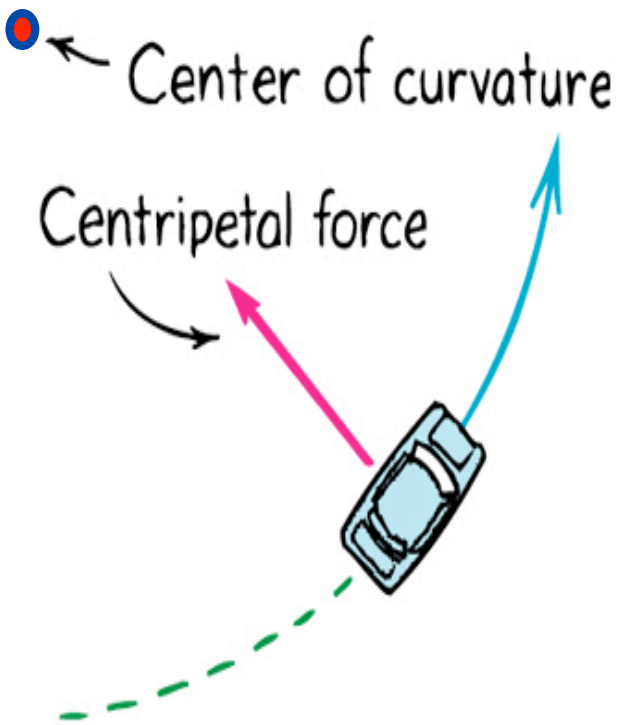
Centripetal Force

- According to Newton, any acceleration must be caused by an outside, unbalanced, force.
- Therefore, centripetal acceleration must be caused by a centripetal force.
- Centripetal force can be found using Newton's Second Law
- $\sum \mathbf{F} = m\mathbf{a}$
- $\mathbf{F_c} = m\mathbf{a_c}$
- $\mathbf{F_c} = m\,\mathbf{v_T}^2/r$



Centripetal Force

- Centripetal force is the name given to the net force required to keep an object of mass m, moving at a speed v, on a circular path of radius, r.
- $Fc = mv_T2 / r$
- Always points towards the center.



Concept check

Object rotates in a circle on the end of a string. Is there a force on the object?

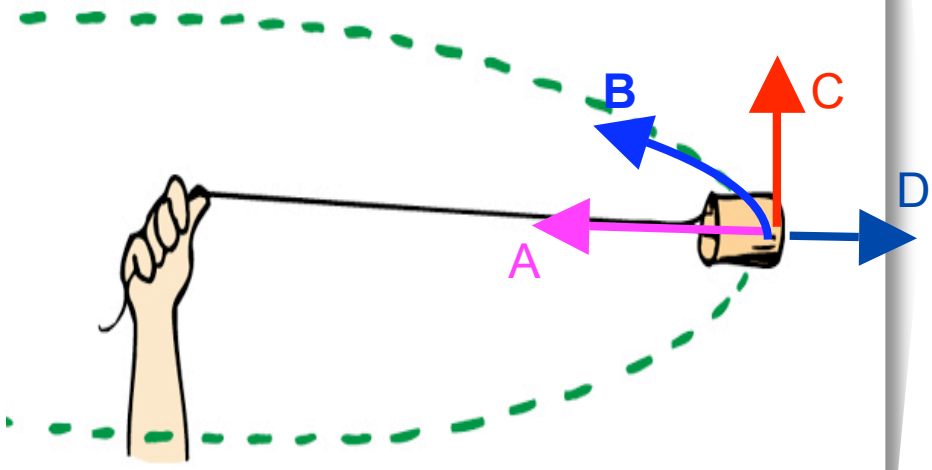
Yes.

What causes the force?

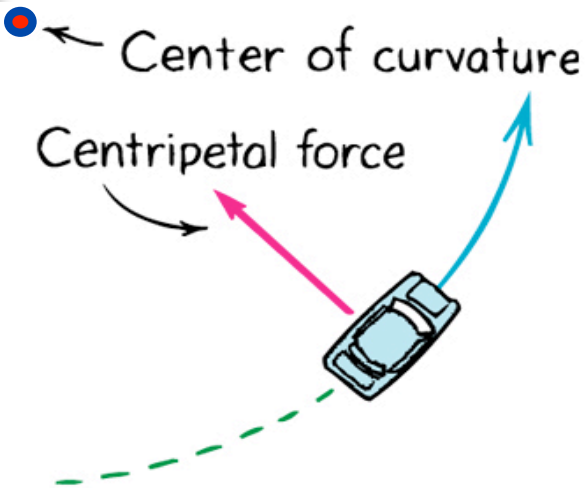
The string.

In what direction is the force?

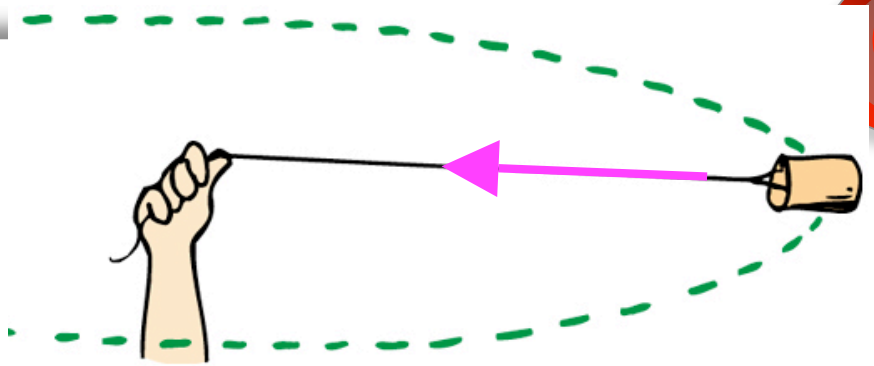
A (Inward).



Centripetal Force Examples

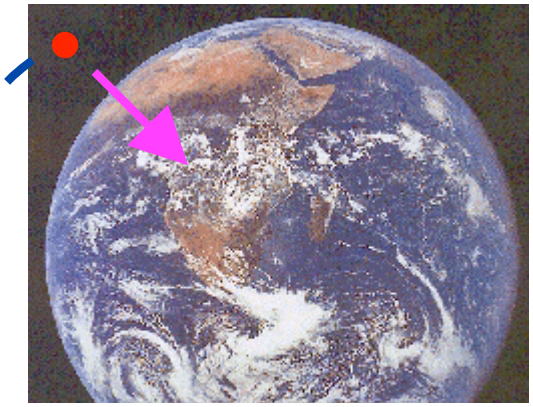


Friction force (tires) is centripetal.



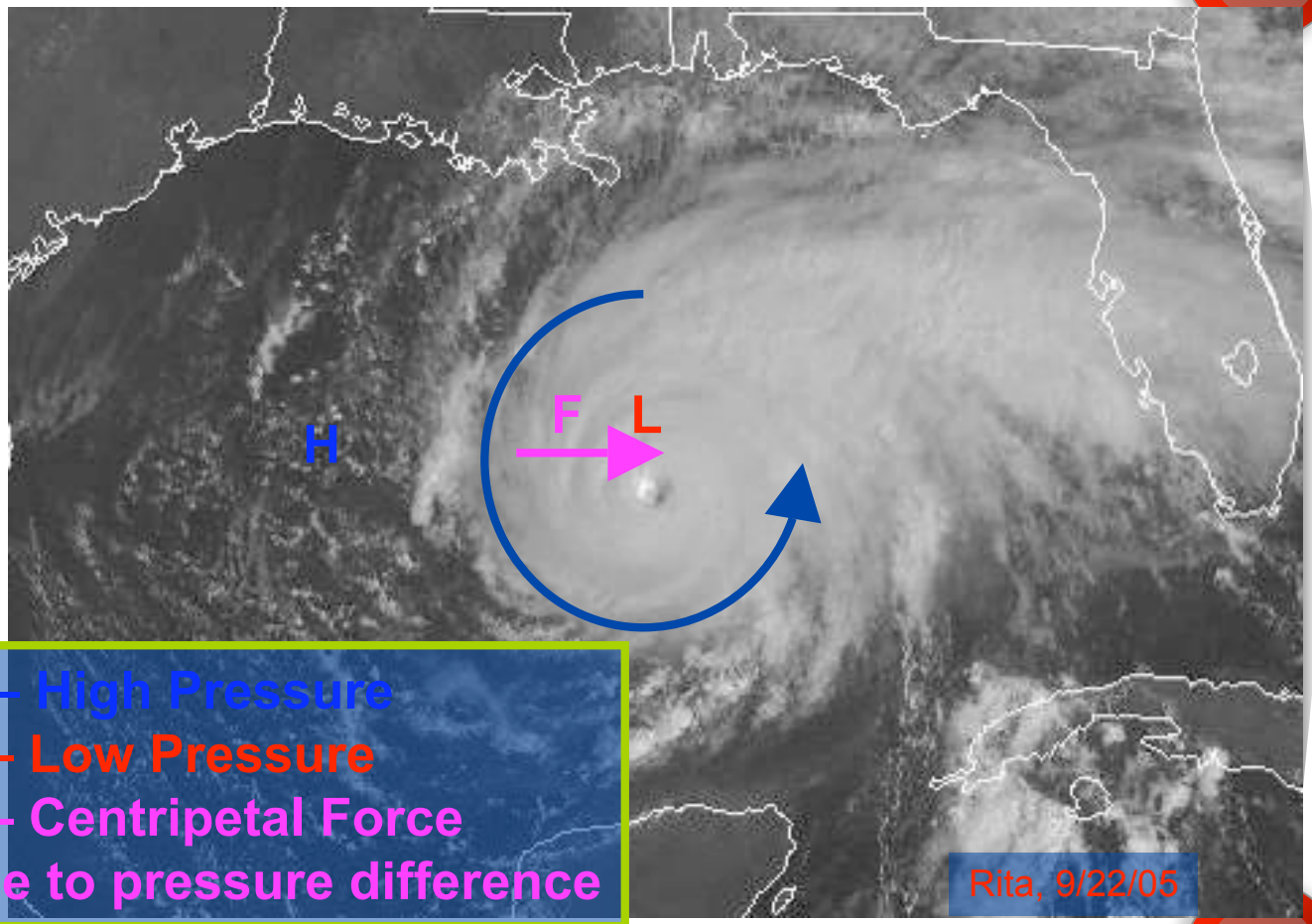
Tension force (string) is centripetal.

Gravity force (on satellite due to Earth) is centripetal



Hurricanes

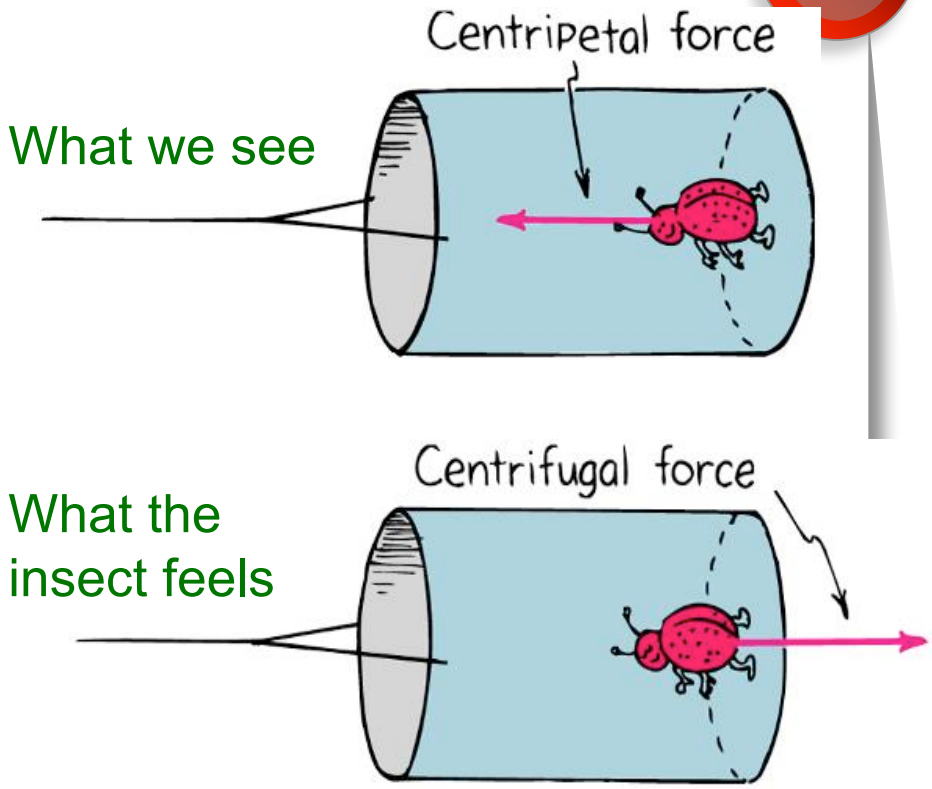
Hurricane's strength (wind speed) depends on how low the pressure gets in the center.



H – High Pressure
L – Low Pressure
F – Centripetal Force due to pressure difference

Centrifugal Force?

- When a centripetal force acts on an object, it appears to the object that there is an outward force. Call this apparent force the centrifugal force.
- There's no such thing!

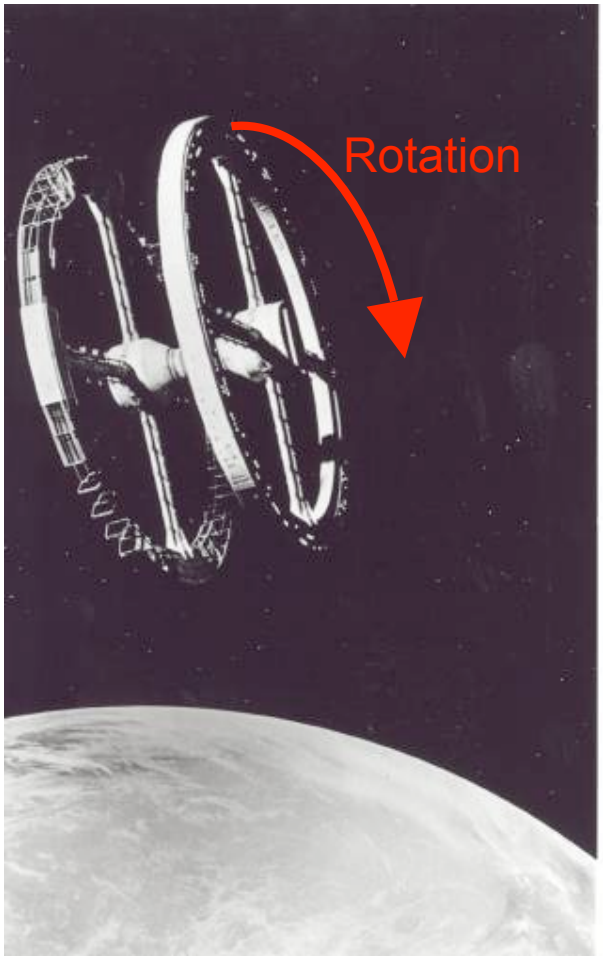


Demo: Bucket over head

- Can I put a bucket full of water over my head without getting wet by rotating it fast enough?
- Forces exerted on the water by gravity plus support force of the bucket are centripetal.
- Apparent centrifugal force presses the water into the bucket.
- What really happens here?

Simulated Gravity

- Centrifugal force could be used to simulate gravity in a space station.
- With the right rate of rotation a person on the outer rim would feel as if they stood on the surface of Earth.
- Scientifically accurate in the movie *2001: A Space Odyssey* (1968)



Example

A model airplane has a mass of .90 kg and moves at a constant speed on a circle that is parallel to the ground. The length of the string that its held by is 17m. It takes 8.2 seconds to make one complete circle.

A) Find the tangential speed of the plane.

B) Find the centripetal acceleration of the plane.

C) Find the centripetal force of the plane.

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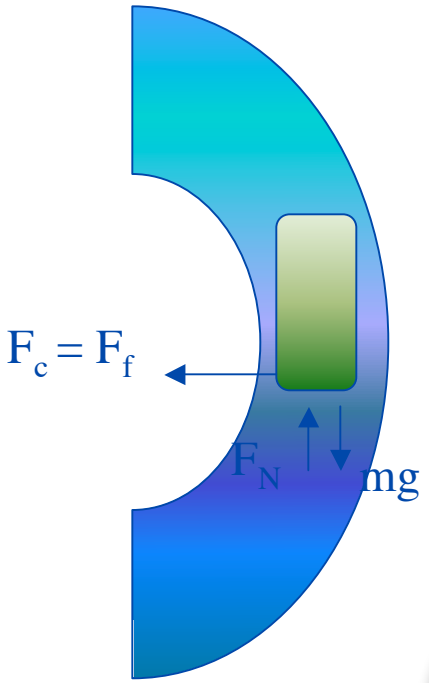
Example

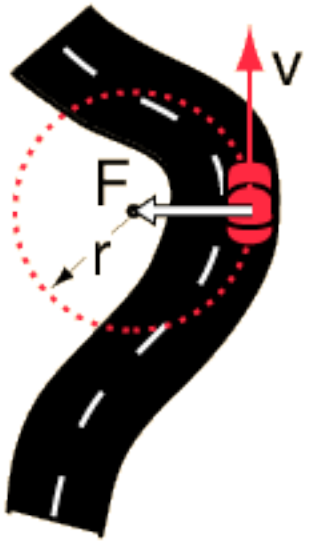
- Given that tires have a coefficient of static friction μ= .72, what is the maximum tangential speed a vehicle can have around a 30m radius turn on the flat ground before sliding?



Answer

$$F_{centripetal} = m\frac{v^2}{r}$$

$\frac{v^2}{r}$ is the centripetal acceleration



- $F_C = m_c v^2 / r \leq \mu F_N$

  $m_c v^2 / r \leq \mu mg$

  $V^2 \leq \mu g r$

  $V \leq \sqrt{(.72)(9.8)(30)}$

  $V \leq 14.5$ m/s